Proton Source Workshop

December 7 & 8, 2010

John Reid

December 8, 2010

Scope

- **RF system description**
- **Booster Solid State RF upgrade project.**
- **Modifications required to achieve 15 Hz beam operation.**
- **Booster RF Cavity tuner issues**
- **Other RF reliability and equipment aging concerns.**
- **Conclusion**

Booster RF Station

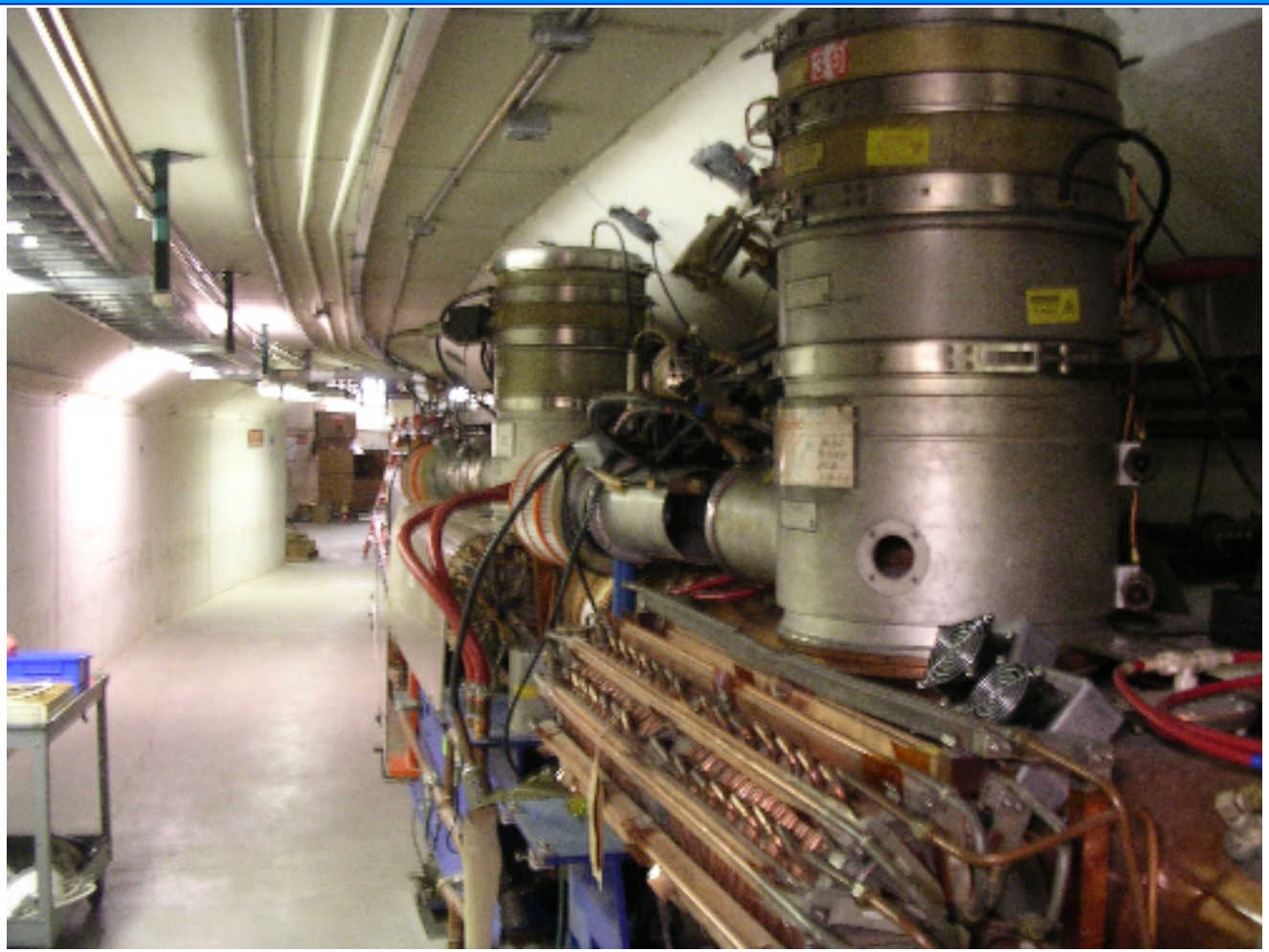
Standard Booster RF Station

Upgraded RF Station with SSD + New Modulator

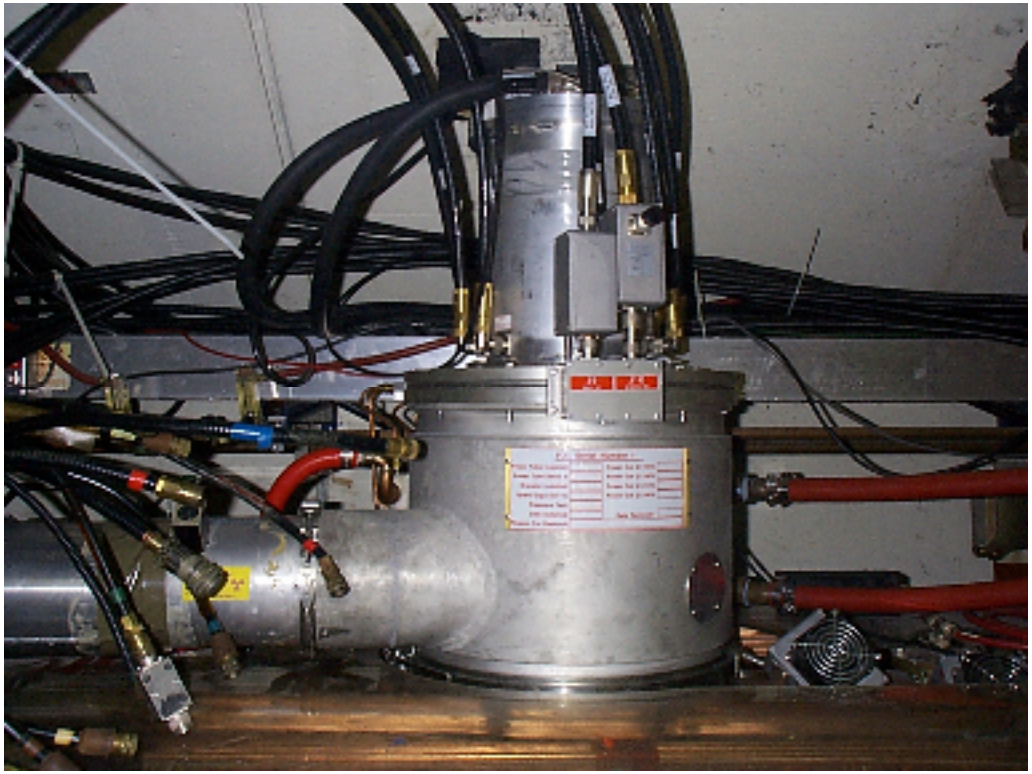
RF System Description

- **19 rf stations installed and operational**
- **2 of the 19 stations are upgraded with SS Drivers, newer Modulators, new 150 kW Power Amplifiers (St 12 [in2001] & St 19 [in 2005]).**
- **Only run18 stations for normal Booster operation keeping one station as a hot spare.**
- **An rf station consists of Ferrite Bias Supply, Series tube modulator, 150 kW power amplifier, rf cavity, & local station controls. 10 stations in the West Gallery run off one anode supply and 9 stations run off another anode supply in the East Gallery.**
- **Booster cavity parameters**
  - Frequency sweep – 30 to 52.813 MHz, present sweep 37 to 52.8 MHz
  - Q at injection (37MHz) ~ 300, Q at extraction (52.8MHz) ~ 1250
  - Peak accelerating voltage per cavity ~ 50 kv

Installed Pair of Booster RF Cavities



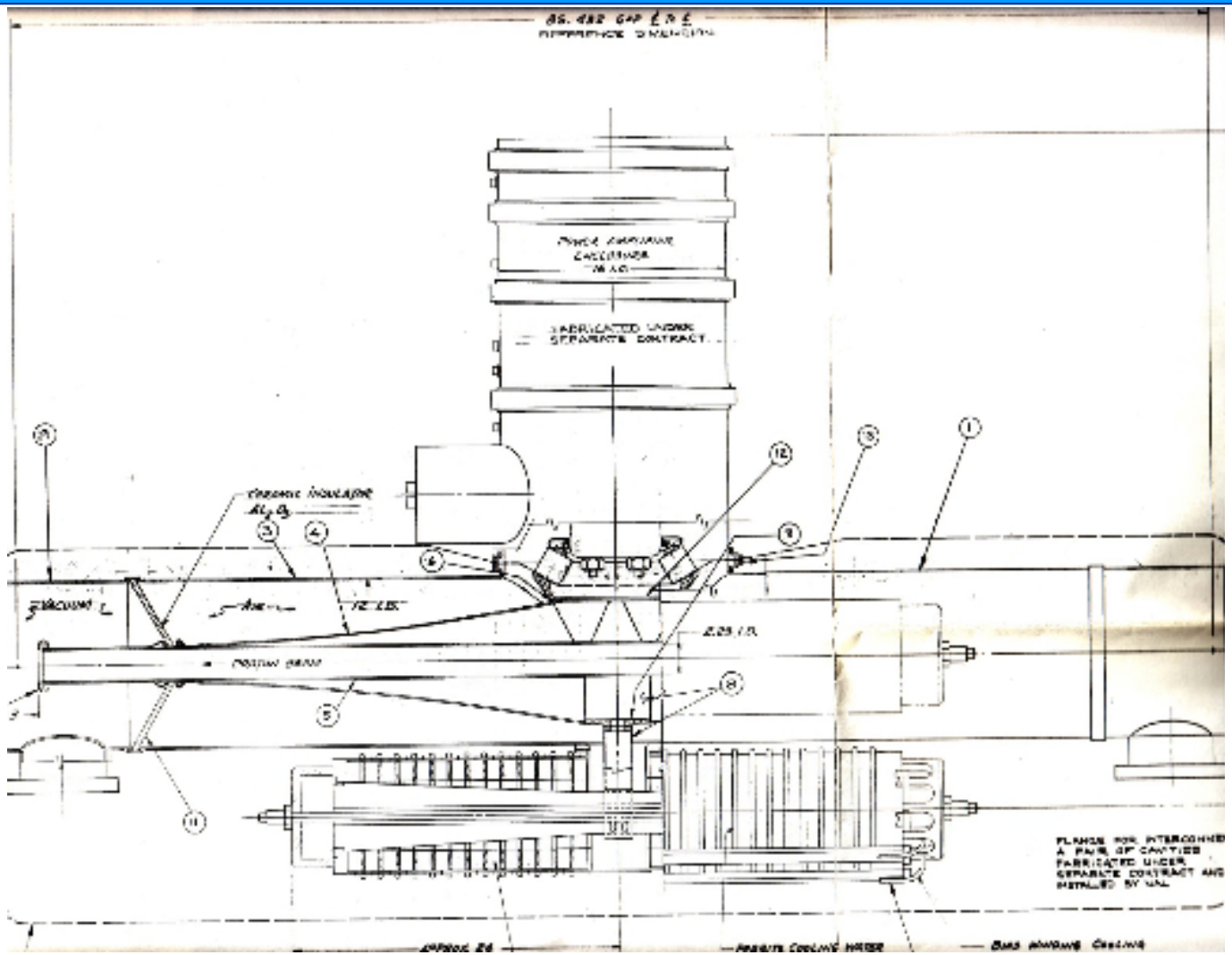
Booster St 12 Amplifier



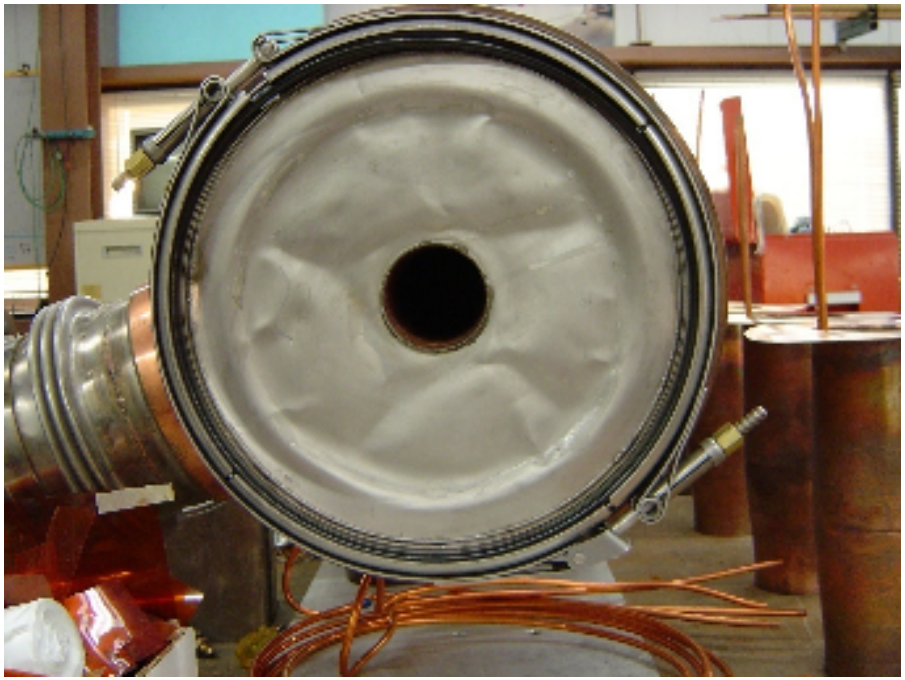
New 150 kW power amplifier on station 12's cavity
Solid State Driven Station installed in 2001

Booster Cavity with support girder

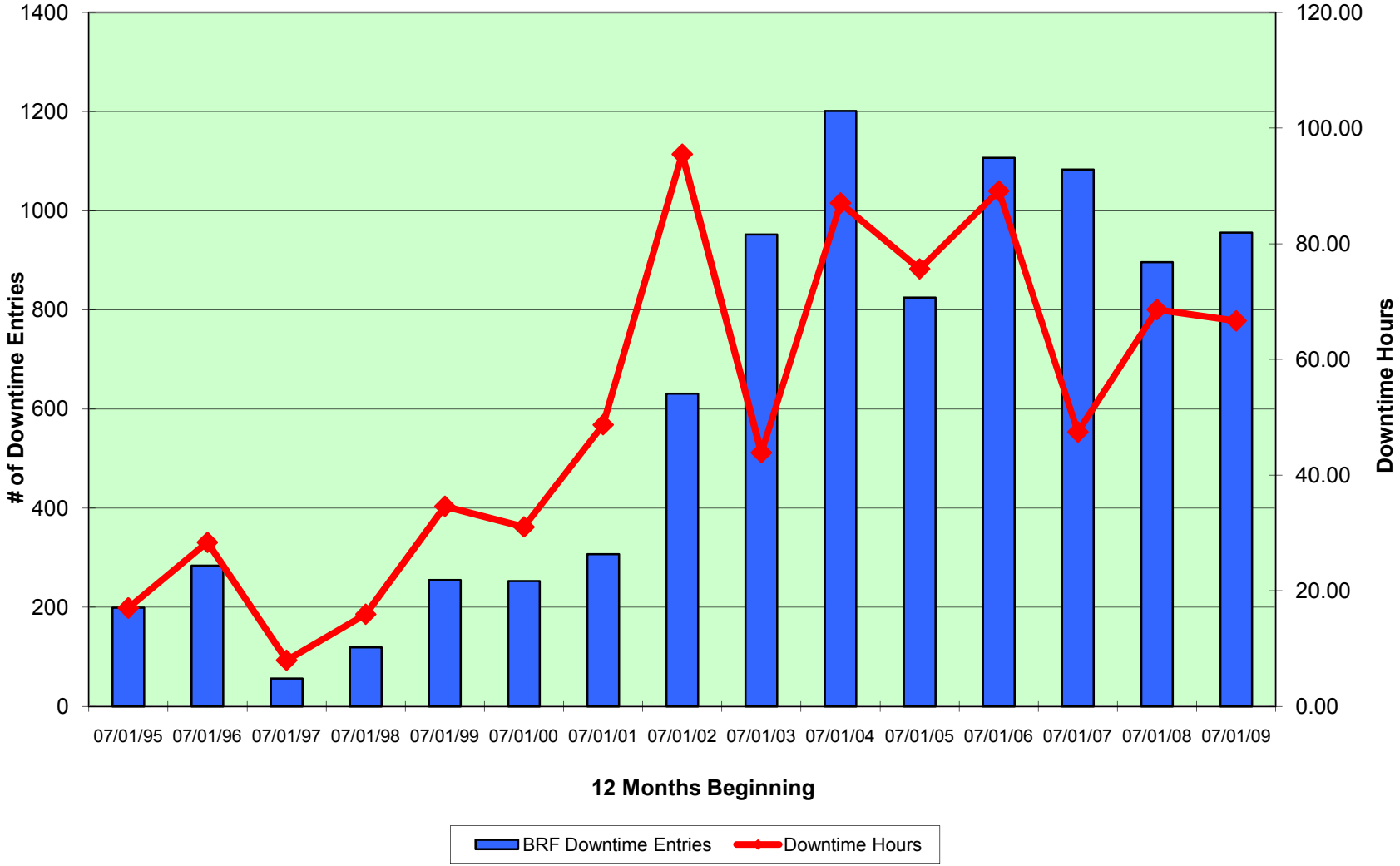
Booster RF Cavity



Standard Booster Cavity Bore - 2.25”



Booster RF Downtime



Booster RF Failures by Year

Equipment	2004	2005	2006	2007	2008	2009	2010
	# Failures	# Failures	# Failures	# Failures	# Failures	# Failures	# Failures
Modulators	23	25	23	15	18	21	20
Bias Supplies	3	8	7	3	3	8	5
Power Amplifiers	20	21	22	23	25	20	17
RF Cavity	6	10	12	10	6	12	9
Anode Supplies	3	3	4	2	3	4	3

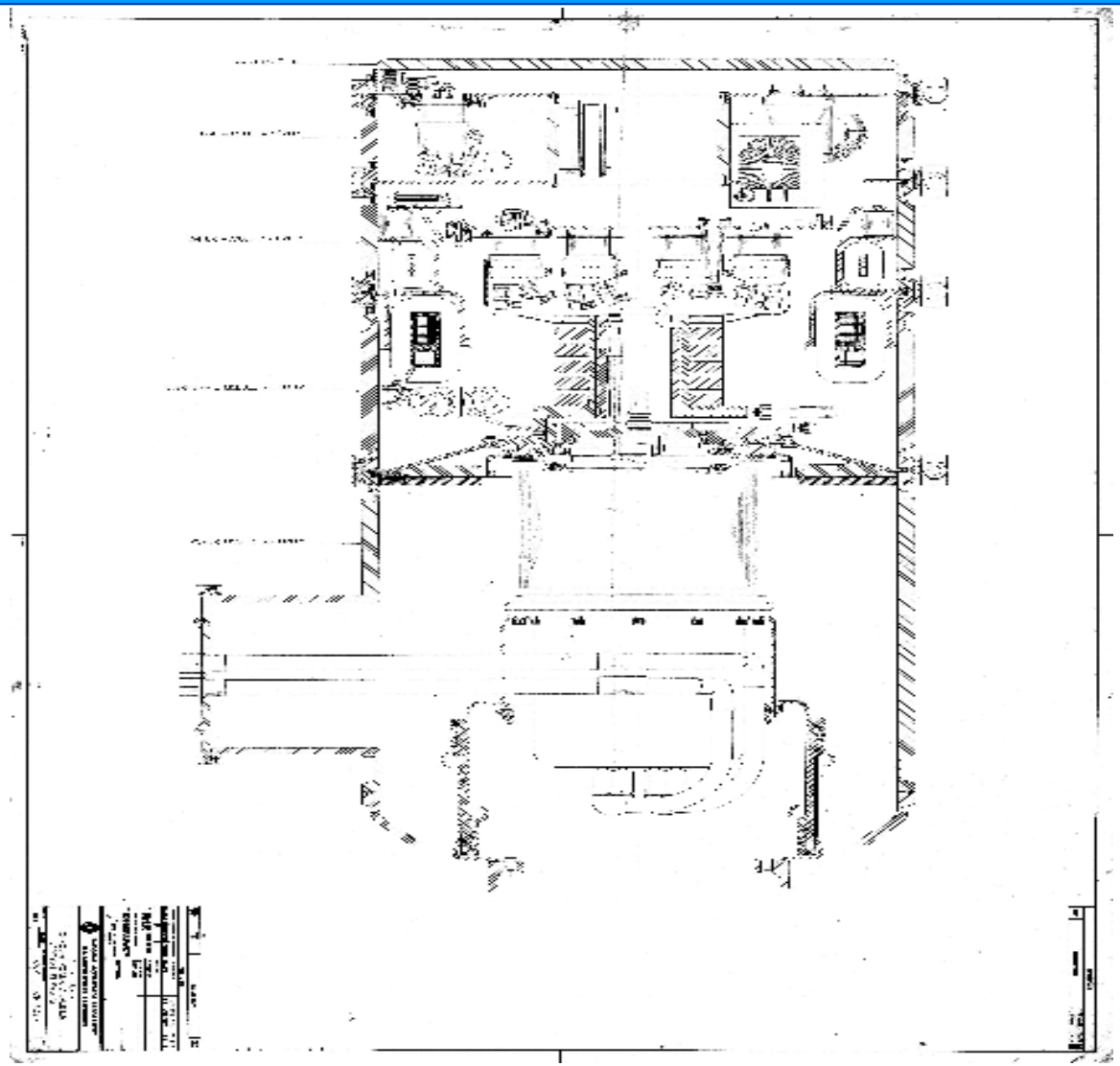
Brief History

- **Booster rf cavities were modified in the mid to late 70's with the following upgrades:**
  - Spark detection system.
  - Monolithic rf coupling capacitor with metalized interface to copper spinnings.
  - Tuners rebuilt using new low loss ferrite
    - Replaced 10 Toshiba M4c21 cores with 10 Toshiba M4D21a cores.
    - 18 Stackpole C2285 cores remain unchanged.
  - Cavities
    - Tuners removed for rebuilding
    - All components thoroughly cleaned
    - Electrical joints tin plated
    - Mode damper mounts add

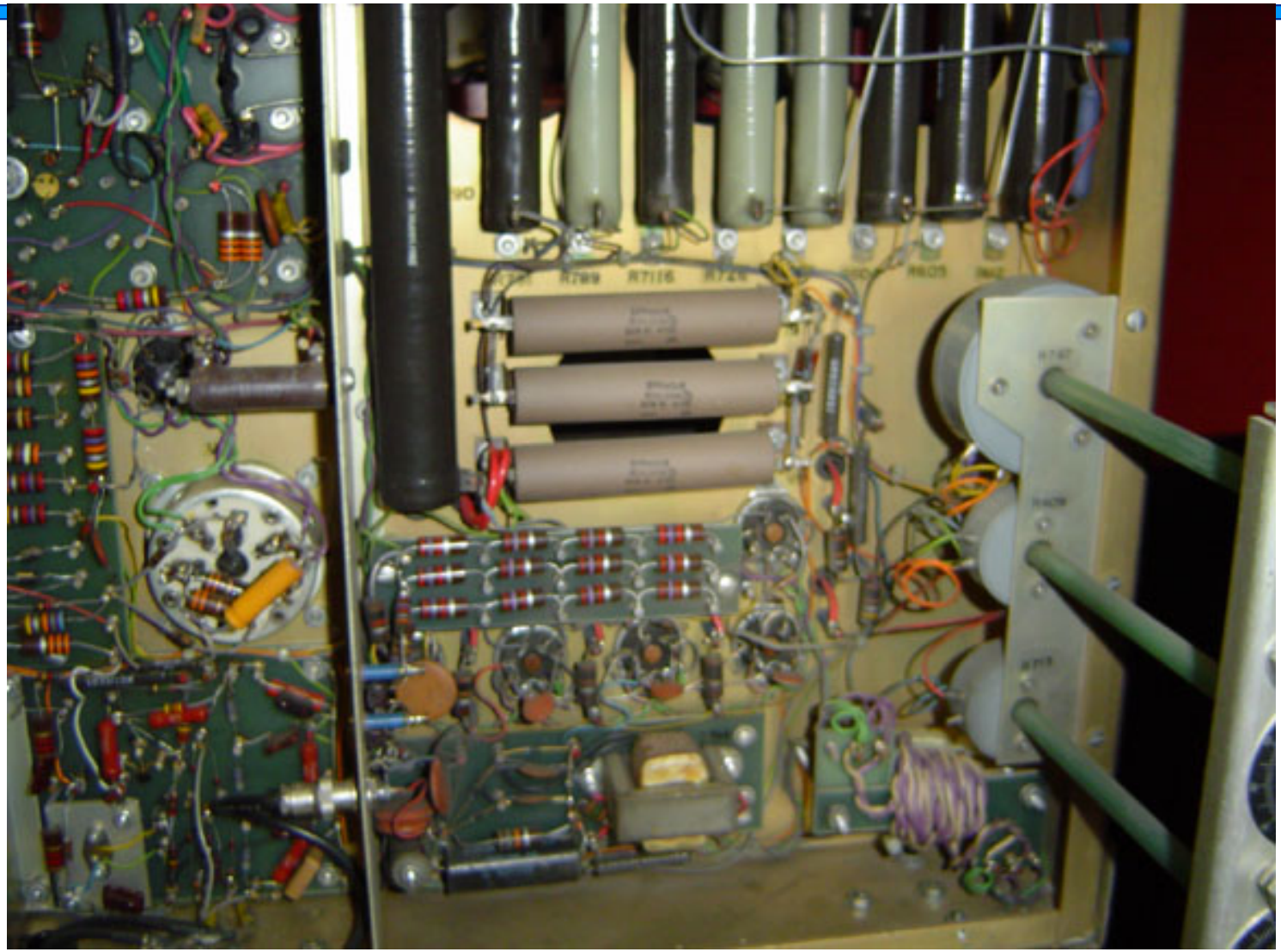
Brief History

- **Modulators**
  - Relics of the past, outdated from day one. Use technology from the 50's.
  - Very few PC boards, mostly point to point wiring.
  - Use a number of glass vacuum tubes, some getting harder to find.
- **Ferrite Bias Supplies**
  - Replaced original Ling power supplies with FNAL design units in the early to mid 70's due to Ling power supply poor pulsing performance.
- **Power Amplifiers**
  - Consist of three sections
    - 6 water cooled 4CW800F tubes - distributed amplifier – last ~9-12 months
    - 14 water cooled 4CW800F tubes - Cascode ampllifier – last ~9-12 months
    - 1 water cooled Y-567B tube – Power module – last ~ 36 months
  - Typical repair time for Booster Power amplifier is ~ 60 man hours

Brief History



Brief History



Brief History

Solid State Driver Upgrade

- **Upgrade Program**

  Build 22 new Modulators (identical to Main Injector rf).

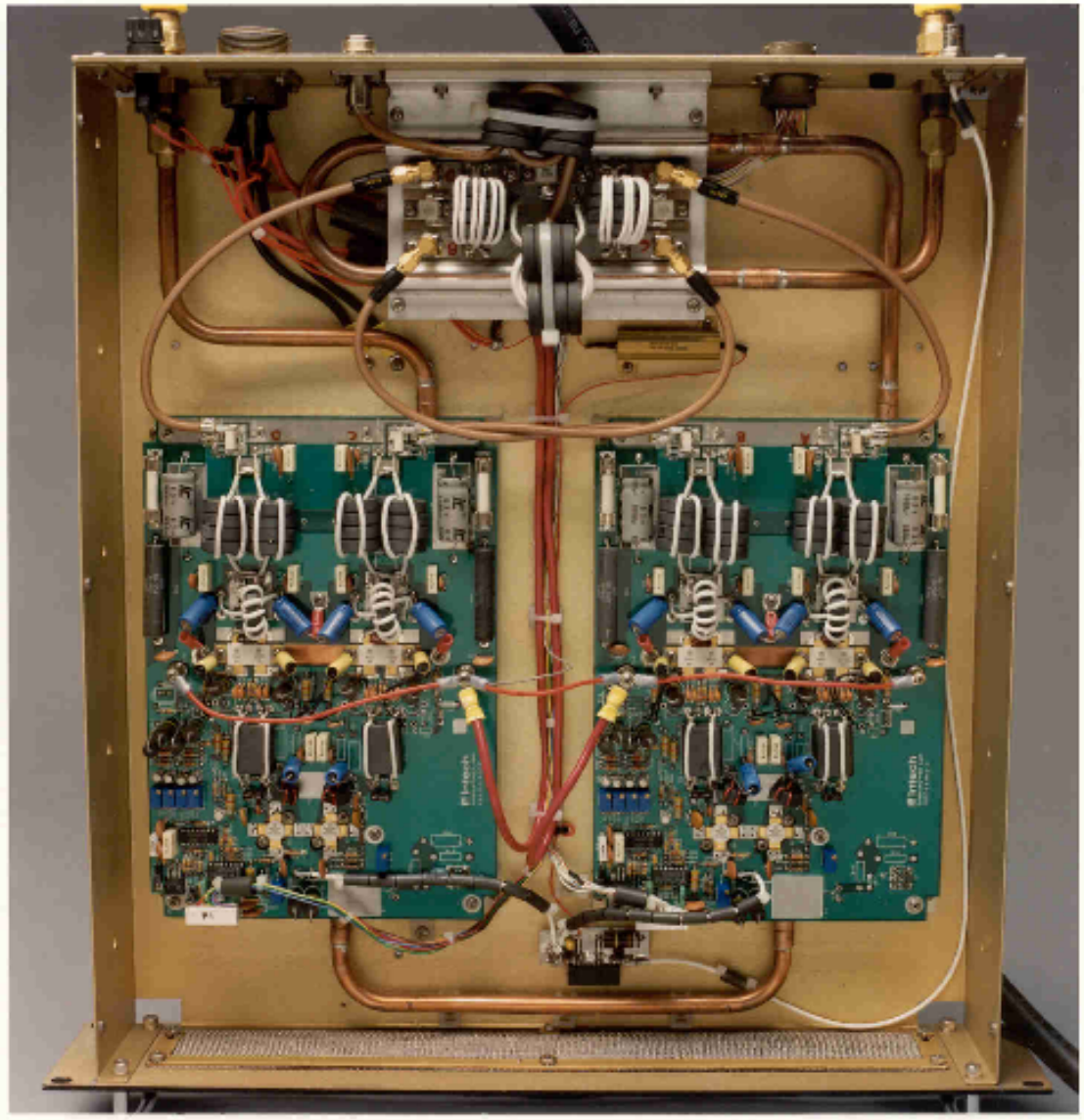
  Build 22 new 150 kW power amplifiers

  Build 22 4 kW Solid State rf amplifiers

- **Present Status**
  - Received 12 frames from vendor, concentrating on completing the first four modulators.
  - Five solid state driver racks assembled and waiting on the completion of 1 kW rf modules.
  - Parts in house to assemble 10 150kW power amplifiers.
  - Many support modules are complete for 22 stations.

1 kW SS Amplifier Module

1 kW SS Amplifier Module



Five SS Amplifier Racks

First 4 Production Modulators @ F0

First 4 Production Modulators @ F0

Modifications to Achieve 15 Hz

- **Booster RF presently running at ~ 7 Hz.**
- **To satisfy proposed future demands, need to run 15 Hz.**
- **Booster rf reliability has been a significant matter for discussion over the last 12 years.**
  - RF system never designed to accelerate beam at the sustained rates now being contemplated.
  - Started with the beginning of MiniBooNE operations in 2002
  - NuMI/MINOS demands have greatly increased the demands on Booster.
  - Existing equipment > 36 years old.
  - Need to maintain a minimum of 900Kvolts / turn
  - Spare Station 19 acts as hot spare to compensate for a down station.

Modifications to Achieve 15 Hz

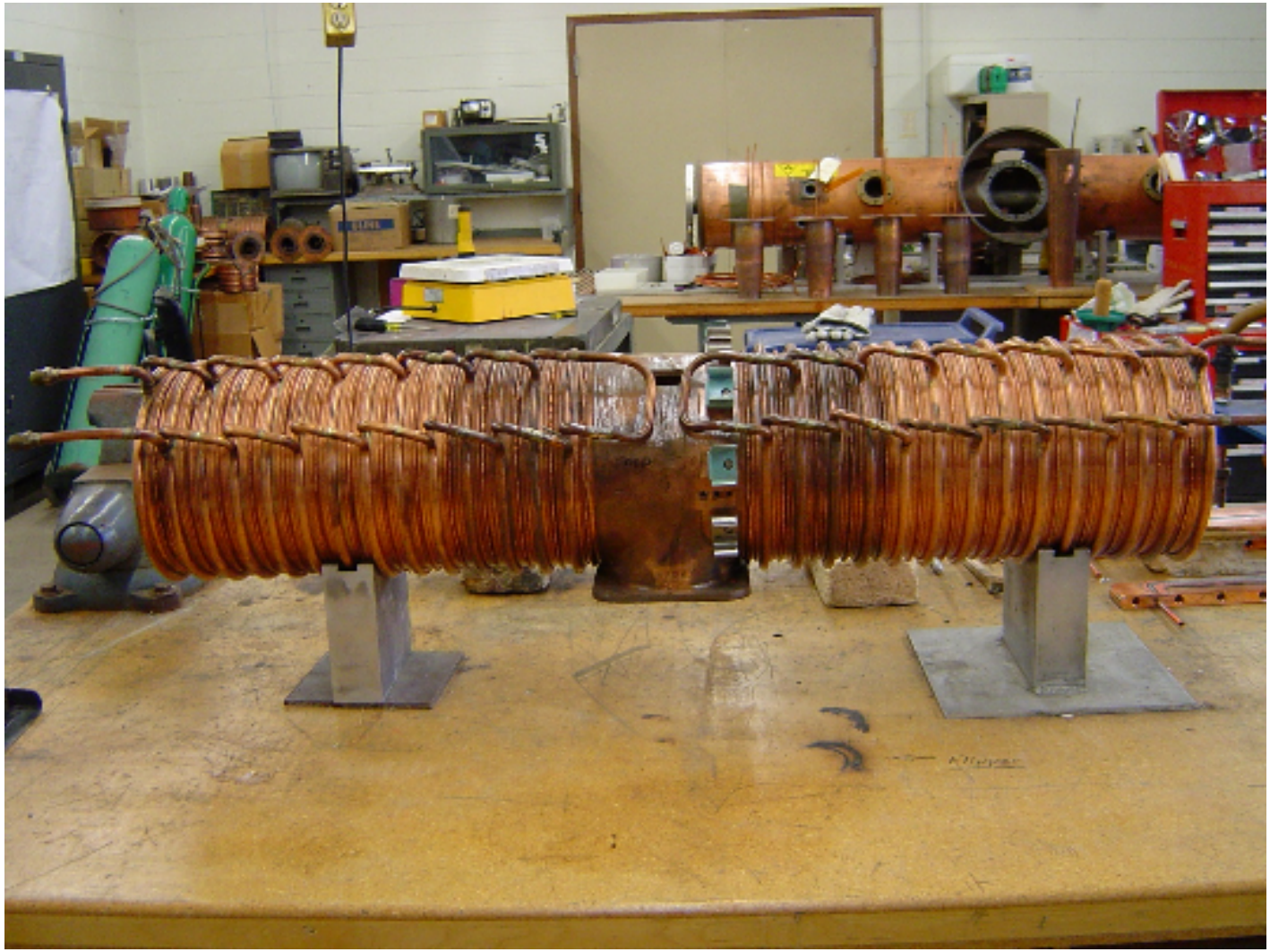
Priority I

- **Complete the Solid State Driver Upgrade project.**
- **Study and determine the limits for ferrite cone heating sans additional cooling. Will we need to connect and repair cooling lines for 15 Hz?**
  - This requires removing cavities and cycling tuners through a rebuilding process.
  - All cavities would be run through the test station and tested at a 15 Hz rate.
- **Study and determine the limits for Ferrite Bias supply main rectifier transformer heating in the West Gallery supplies.**
  - Propose to upgrade transformers and SCR packages with what is used in the East Gallery Ferrite Bias supplies. This also eliminates the old PVC heat sinks that leak when an LCW pressure surge occurs.
- **Check condition & operating temperature of high power AC distribution.**
- **Finish the LCW distribution system upgrade back to CUB.**

Priority II

- **Replace the East and West Gallery Anode Supply Main Rectifier Transformer. Present transformers are 40 years old.**
- **Replace Step Start 13.8kV VCB for both Anode Supplies**
- **Update select internal components and install new controls.**

Booster Cavity Ferrite Tuner housing with Ferrites only

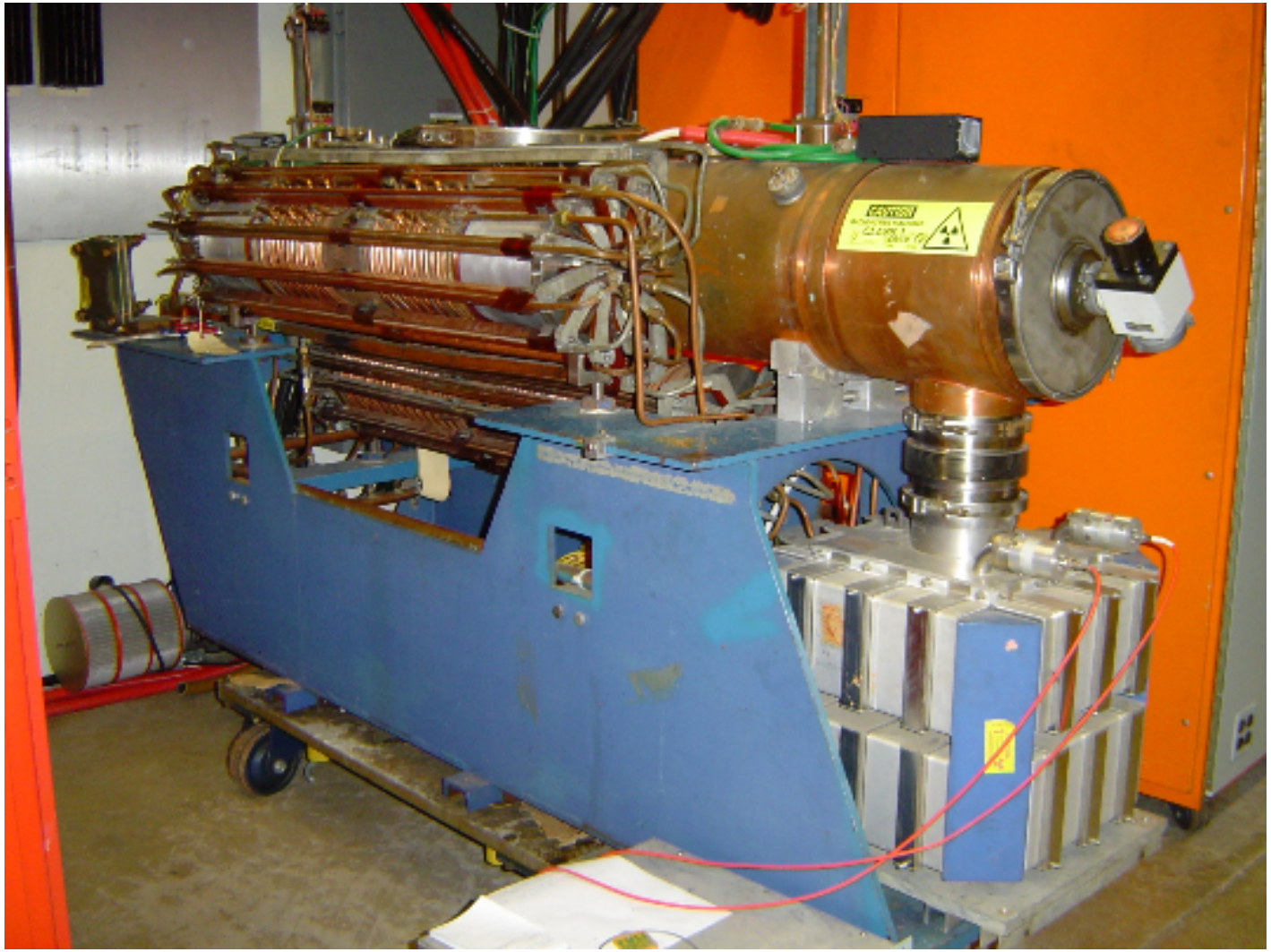


Tuner Cones

Bare copper Castings

5 mil Cu clad stainless skins

Booster Test Station at MI60



Other RF Reliability Issues

- **Update HV Choke in rf cavity.**
- **Increase mode damper power dissipation (load).**
- **We are replacing all Station cables (including HV) from upstairs to tunnel during the SS Driver upgrade.**
- **Replace old rf sum balancing circuit with new global amplitude & phase regulator circuits so amplitude and phase of "A" stations and "B" stations track the request.**
- **Rebuild prototype Booster rf cavity using spare production center castings (inner & outer) to achieve a good operational spare. Start Jan 1, 2011.**

Conclusion

- **Implement Global Amplitude & Phase control.**
- **Need required funds to complete SS Driver Upgrade.**
- **Study heating in the West Gallery Ferrite Bias Supply Transformers.**
- **Rebuild Booster prototype cavity.**
- **Continue to build spare tuner cones**
- **Build additional spare tuners.**
- **Install diagnostic measuring devices on a couple of the existing rf cavities in the tunnel to track thermal heating.**